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Pellet to Part Manufacturing System for CNCs

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OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

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Energy and Transportation Sciences Division
Advanced Manufacturing Office

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ABSTRACT

Oak Ridge National Laboratory's Manufacturing Demonstration Facility worked with Hybrid Manufacturing Technologies to develop a compact prototype composite additive manufacturing head that can effectively extrude injection molding pellets. The head interfaces with conventional CNC machine tools enabling rapid conversion of conventional machine tools to additive manufacturing tools. The intent was to enable wider adoption of Big Area Additive Manufacturing (BAAM) technology and combine BAAM technology with conventional machining systems.

1. PELLET TO PART MANUFACTURING SYSTEM FOR CNCS

This phase one technical collaboration project (MDF-TC-2016-083) began on February 1, 2016 and was completed on February 14, 2018. The collaboration partner, Hybrid Manufacturing Technologies (HMT), is a small business. A polymer extruder has been successfully developed and integrated with the machine control as well as with ORNL Slicer. Calibration of the machine was completed, which led to successful prints including a miniature chair.

1.1 BACKGROUND

HMT is a start-up based outside of Dallas, Texas. HMT's goal is to bridge the gap between additive manufacturing and CNC subtractive machining. They retrofit existing CNC machines from manufacturers like Hurco (Fig. 1) and Haas (Fig. 2) with their custom designed metal additive heads as well as inspection heads. Using their current technology, HMT can grow a part with their metal heads, through a directed energy deposition (DED) process, and then subtract away any excess material to get the final product to exact shape. This is all done without human intervention by an automated tool change system that can switch between additive and subtractive heads on the CNC. The partnership with ORNL is aimed at increasing the product line at HMT by adding polymer additive manufacturing to their capabilities.

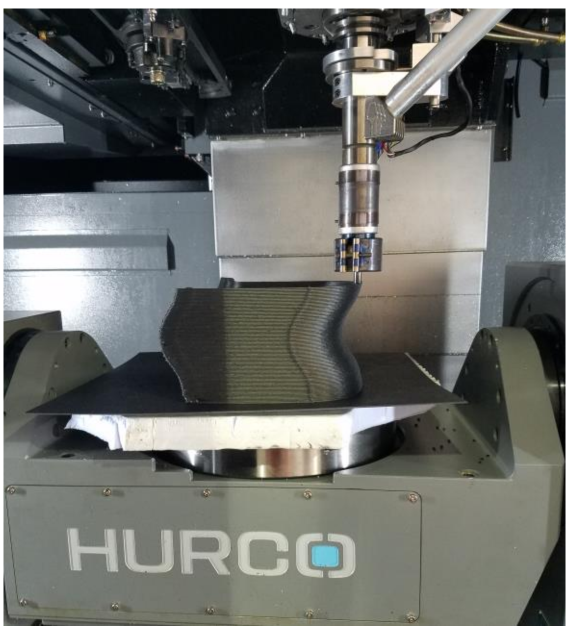

Fig. 1. First generation extruder printing a miniature chair on a Hurco CNC

Fig. 2. The second-generation extruder in a testing setup in a Haas VF-5 CNC machine

1.2 TECHNICAL RESULTS

HMT designed and engineered a small pellet fed extruder that could be held by a machining spindle leveraging components and the processes from conventional injection molding and extrusion. The extruder needed to be designed specifically for going inside a CNC machine. This meant it had to fit into a tool changer for automatic loading and unloading, but it also needed to mate correctly with a machining spindle, which would be the power source (an approach patented by Hybrid). It also had to be small and light weight. A long barrel reduces the printable z-height of the machine, and a wide barrel doesn't fit the tool changer. The first-generation of this extruder (Fig. 1) was intended to explore if the constraints for tool changeability and practical deposition rates 100x conventional desktop printers could be realized simultaneously. It was bulky and had some design limitations that made it difficult to clean the screw/barrel and difficult to disassemble as needed to measure/track screw wear.

With input from ORNL, a second-generation of the extruder (Fig. 2) was constructed and saw many improvements over the first generation. The weight was reduced by 30% (down to less than 4kg), which meant less mass to heat up and resulted in faster heating and cooling times for the extruder. A mounting redesign meant nozzles could be easily removed without any further disassembly. The screw can now be removed through the top or bottom of the extruder as needed for cleaning and replacement.

At the start of the partnership with ORNL, HMT was struggling to make usable parts from the polymer extruder (Fig. 3). With assistance from ORNL, HMT was able to quantify the extruder by recording flowrates and doing calibration prints (Fig. 4). Figure 4 shows a calibration print used to properly determine flowrates for varying corner radii and start and stop parameters. The corner of the print shown in the center of the photo shows the start and stop location of the print known as the seam. With proper tuning, the start and stop becomes less noticeable. This tuning is done through ORNL Slicer. A specific syntax was created for each of the two HMT hybridized machines, Haas and Hurco. The software and parameters were modified specifically for the process as desired by HMT to allow them to print end-use parts (Figs. 5 and 6). Chopped carbon fiber reinforced acrylonitrile butadiene styrene (ABS) plastic pellets has proven to be a successful and reliable feedstock for the HMT system.

Fig. 3. Early part produced by HMT

Fig. 4. Calibration print showing starts and stops

Fig. 5. A hexagon printed with the second-generation extruder using a 3mm diameter nozzle on an AMBIT™-dextrous Haas CNC machine

Fig. 6. Parameter development for 5mm diameter nozzle with the second-generation extruder on the AMBIT™-dextrous Haas system

1.3 IMPACTS

The impacts of this project are significant. This project lays the groundwork to give virtually any floor standing CNC machine tool owner the ability to upgrade their CNC machine to extrude polymer for additive manufacturing capabilities. The ability to convert an existing CNC machine to have extrusion capabilities creates and easy adoption path for BAAM technology, which costs significantly less than investing in conventional industrial grade filament extruders. Facilitating the automated switch from extrusion to machining enables the ability to machine extruded parts in-process, which realizes the freedoms of additive manufacturing without sacrificing machining tolerances and surface finishes.

Moving forward, HMT plans to continue developing this system, which will provide the ability to add metal and polymer materials in this additive and subtractive manufacturing process. This will enable multi-material parts to be produced using both materials as either build or support material. Adding polymer directly onto metal components can provide a cheap, efficient sacrificial material for work holding, which has the potential to reduce the complexity of metal part repair (a workflow claimed in an HMT patent).

1.3.1 SUBJECT INVENTIONS

There are no subject inventions that resulted from this project.

1.4 CONCLUSIONS

Polymer additive manufacturing has been successfully adapted to work within the HMT system, giving them a new product line. The second-generation extruder has proven to be very responsive and reliable with carbon fiber ABS pellets. ORNL Slicer has been fully integrated for use with both Haas and Hurco CNC machines with the polymer additive manufacturing. The next step for HMT is to distribute the new polymer head to clients to begin field testing, which is scheduled for the end of March 2018. The next step for ORNL is to continue working on material development and calibration strategies so that the HMT process can be extended to new industries.

2. HYBRID MANUFACTURING TECHNOLOGIES BACKGROUND

In 2007, the founders of HMT undertook the task of developing a solution to marry the freedoms of additive manufacturing with the precision of CNC machining. The key objectives were to provide a practical means for hybrid manufacturing. This included the development of robust and compact directed energy deposition heads and integration methods that did not require modification of the structural parts of the CNC machine.

In 2007, active use of a high-speed milling machine was initiated at De Montfort University's Additive Manufacturing (AM) and 3D printing research laboratory. The cross-pollination of additive and subtractive technologies led to a 4-year UK-based research project named RECLAIM (REmanufacture of high value products using a Combined LAser cladding, Inspection and Machining system) with support from the Technology Strategy Board. This research endeavor has matured into the AMBIT™ tool-changeable deposition system. Project collaborators included: Airfoil Technologies International Llc, Cummins Inc, De Montfort University, Delcam plc, Electrox Ltd, Manufacturing Technology Centre Ltd, TWI Ltd, Precision Engineering Technologies Ltd, and Renishaw plc.

Commercial exploitation led to the formal founding of HMT in 2012 by Dr. Jason Jones and Peter Coates as a spin-off from a collaborative research and development project.